State of California
The Resources Agency
Department of Water Resources

GROWTH INVESTIGATIONS OF WILD JUVENILE STEELHEAD (ONCORHYNCHUS MYKISS) IN THE FEATHER RIVER USING MARK AND RECAPTURE TECHNIQUES

Interim Report
SP-F10, Task 3B

Oroville Facilities Relicensing
FERC Project No. 2100

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GRAY DAVIS
Governor
State of California

MARY D. NICHOLS
Secretary for Resources
The Resources Agency

MICHAEL SPEAR
Interim Director
Department of Water Resources

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Prepared by:

California Department of Water Resources
Division of Environmental Services
3251 S Street
Sacramento CA 95816

Contact:

Jason Kindopp
(530) 534-2381
jkindopp@water.ca.gov

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Summary

The objective of mark and recapture sampling was to investigate site-fidelity and growth of wild rearing juvenile steelhead (*Oncorhynchus mykiss*).

Mark and recapture experiments of wild juvenile steelhead were performed between June and August 2002 at four locations within the low flow channel (LFC) of the Feather River. A total of 547 steelhead were captured, measured and weighed. Four hundred twenty-four of the steelhead met predetermined tagging criteria and were thus given an individual mark and released back into the river. Only 22 steelhead were recaptured, 15 of which were initially tagged in Hatchery Ditch.

Most (86.4%) steelhead were recaptured at their original release location, which may indicate fairly strong site fidelity. The greatest distance any one steelhead traveled was 4.8 river miles. Steelhead were recaptured on average 30 days after initial tagging and release.

Data gathered indicates that steelhead rearing in the lower portions of the LFC are larger and in better condition than those rearing near the upper end. Steep Riffle may represent the most ideal rearing environment for juvenile steelhead, assuming long-term exposure to warmer water temperatures is not detrimental. Additional data must be collected to expand and validate the limited results gained in 2002.

A pilot enclosure study was also performed to test our ability to rear steelhead in enclosed areas within the river to monitor growth in two highly different temperature settings. The pilot study was successful in preventing fish from escaping and was also successful in preventing vandalism. Expanded mark and recapture and enclosure studies will both be implemented in June, 2003.

1.0 Introduction

The operation of the Oroville Facilities may affect water temperature, which may influence rearing juvenile steelhead trout (*Oncorhynchus mykiss*). Exposure of juvenile steelhead to high water temperatures may result in acute direct mortality or in sub lethal chronic thermal stress that can be evidenced through indicators such as disease outbreaks, reduction in growth and loss of appetite.

Laboratory studies on Feather River hatchery and naturally spawned steelhead suggest that rearing juveniles prefer temperatures between 62 and 68 °F (16.7 and 20 °C) (Myrick 1998). Furthermore, naturally spawned Feather River Steelhead have been observed to rear successfully at water temperatures near 65°F (18.3 °C) (DWR and USBR 2000). Young-of-year Feather River steelhead have also been observed rearing in habitats where average daily water temperatures were 63°F (17.2 °C), and where daily maximal water temperature exceeded 66°F (18.9 °C)(DWR and USBR 2000). To complement the existing laboratory study and the continued gathering of observational data by snorkeling (SP F-10, Task 3A), additional field studies were proposed. As part of Oroville Facilities Relicensing study plan F10-Task 3B, mark and recapture and enclosure growth experiments were conducted to evaluate the effects of temperature on juvenile steelhead rearing in the Low flow Channel (LFC).

Average monthly water temperatures in the reach of the Feather River from the Fish Barrier Dam to the Thermalito Afterbay outlet range from 47°F in winter to 65°F (18.3 °C) in the summer. Water temperatures downstream of the Thermalito Afterbay outlet are generally warmer, with the maximum mean daily water temperature at the Thermalito Afterbay outlet reaching approximately 70°F (21.1 °C) in the summer. Because daily summer water temperatures often exceed 70°F below the Thermalito Afterbay outlet, it is unlikely that steelhead rear in High Flow Channel (HFC) (DWR and USBR 2000). Snorkel surveys have confirmed that the area below the Thermalito Afterbay outlet does not support rearing steelhead (DWR and USBR 2000). To this end, field experiments were focused on the area above the Thermalito Afterbay Outlet, specifically the LFC (Figure 1.1-1). Because juvenile steelhead rear in the river all year and are expected to be in the river during months when increased water temperatures are probable, field experiments were conducted in June, July and August.

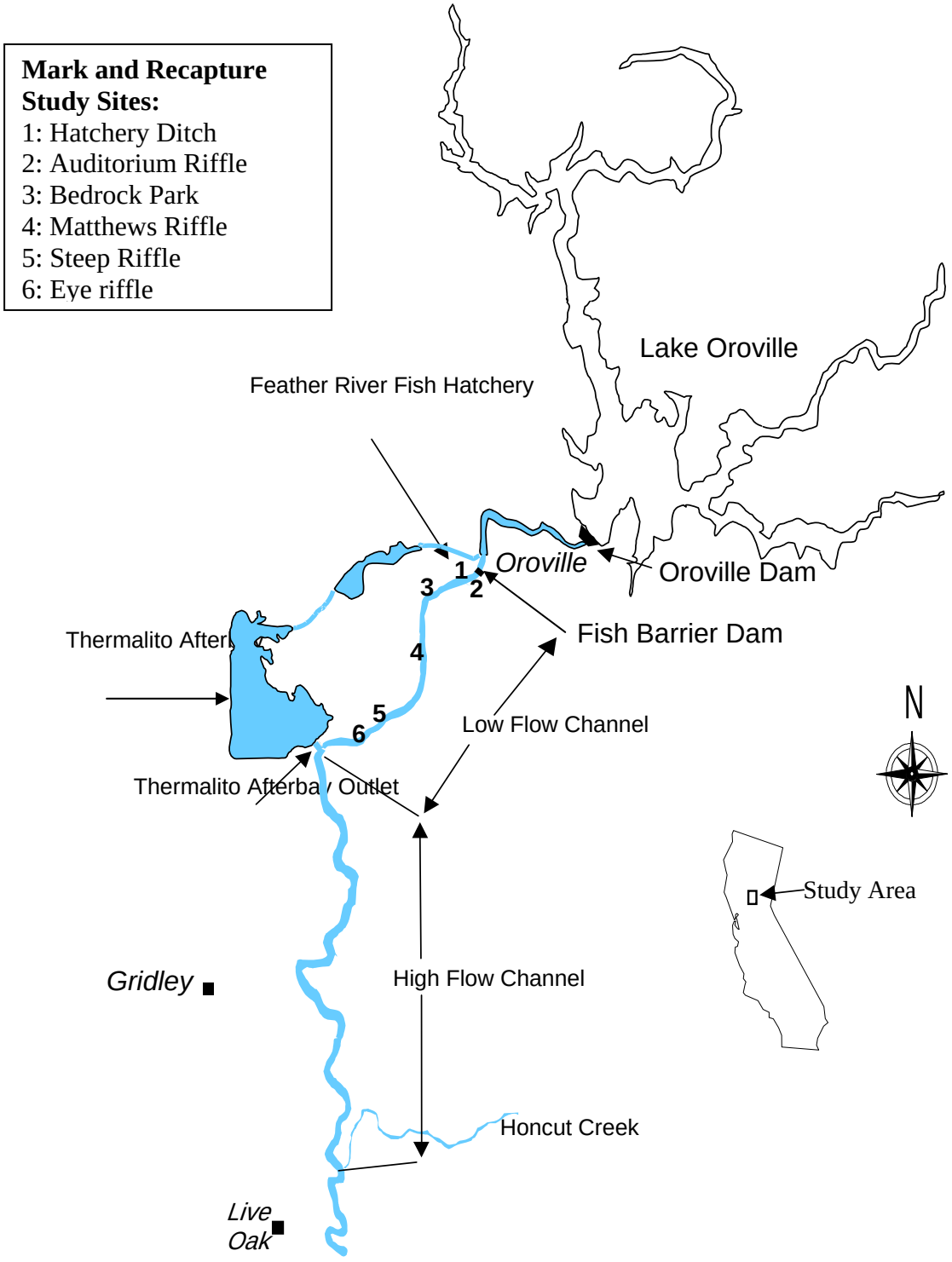


Figure 1.1-1. Map of the Feather River study area. Drawing is not to scale.

2.0 Methods

2.1 Mark and Recapture Study

The objective of this sampling was to provide information complimentary to the enclosure of hatchery steelhead, but that will not have artifacts of the enclosure experiment. Repeated sampling of wild juvenile steelhead was designed to investigate site-fidelity and growth.

Wild juvenile steelhead were collected by beach seining and electrofishing (Smith-Root Model 12 backpack electrofisher) at five riffles in the LFC (see Figure 1.1-1). Fish were collected from 0900-1200 on a monthly basis between 18 June and 21 August 2002. Upon collection, fish were placed in buckets of fresh river water. Unwanted species were released upon recovery. All steelhead and Chinook salmon were kept for further processing. Once each site was thoroughly sampled, all steelhead and Chinook were placed in chilled and aerated water for processing. All Chinook were measured and immediately released. All Steelhead were anesthetized with TRICAINE-S, (Brand of Tricaine Methanesulfonate, manufactured for Western Chemical, Inc.), weighed, measured (to the nearest mm fork length) and examined for unique tagging marks (after the initial tagging event). All unmarked steelhead greater than 35 mm were marked using combinations of latex elastomer (manufactured by Northwest Marine Technologies, Tumwater, WA) and photonic marking formulation (manufactured by New West Technologies, Santa Rosa, CA). Every individual was assigned a unique mark using neon red, blue, orange, yellow, or green colored tagging material in various body locations. Tagging locations included nose, upper and lower caudal peduncle, and dorsal and anal fins. All fish were released as close to the original recapture site as possible. Steelhead mortalities were preserved for future research. Measurements of water temperature (in situ temperature loggers were placed at several LFC locations for the months of June, July and August), effort, weather, and flow were also recorded during each sampling event.

Condition Factor (K) was used to assess changes in growth by location on a standardized basis. The following equation was used:

$$K = 100000*W/FL^3$$

where W = weight in grams and FL = fork length in millimeters.

2.2 Enclosure Pilot Study

A pilot enclosure experiment was conducted to assess the possibility of rearing hatchery steelhead in enclosed areas within the river to monitor growth in two highly different temperature settings. Although larger steelhead were used in 2002 (as compared to what will be used in 2003), the enclosures were effective in preventing fish from escaping and preventing large-scale vandalism.

Due to manufacturing delays only two enclosures were obtained and subsequently placed in the river on August 13, 2002. One enclosure was placed at the upper end of the LFC at Cottonwood Riffle (RM 66.7), and one was placed at the lower end of the LFC at Eye Riffle (RM 60.1). Ten hatchery steelhead (mean fl = 85 mm) were placed at each location. High LFC flows forced the removal of the Cottonwood enclosure on August 22 (increased flows for IFIM studies in the LFC of 2002 forced the removal of the Cottonwood enclosure and submerged the Eye riffle enclosure, allowing some steelhead to escape). Although the flow increase allowed four steelhead to escape, the Eye Riffle enclosure was able to stay in place until September 19, 2002 (37 days).

3.0 Results

3.1 Mark and Recapture

In 1,270 shocking minutes we captured a total of 547 steelhead, of which, 424 were tagged. A total of 12 (2.2%) steelhead were killed during sampling and processing. These fish were all kept frozen for future otolith and genetic analysis. The majority of Steelhead were captured in Hatchery Ditch (n=226), followed by Steep Riffle (n=111) and Matthews Riffle (n=71) (Table 3.1-1). Catch per unit effort (CPUE) was greatest in Hatchery Ditch (1.4 fish/minute) and lowest at Bedrock Park (.2 fish/minute) (Table 3-1.1).

Table 3.1-1. Summary of sampling effort, fork length and weight data of Steelhead collected during mark and recapture sampling.

Location (River Mile)	Percent of all Steelhead tagged	Total Number of Steelhead Captured	Number of Steelhead Tagged	Shocking Minutes	CPUE (steelhead/ minute)	Mean Fork Length (mm) (± 1 SD)	Mean weight (g) (± 1 SD)
Hatchery Ditch (66.6)	50.7	226	215	185	1.4	60.9 (10.3)	3.0 (1.6)
Auditorium Riffle (66.7)	n/t	45	0	225	0.2	58.9 (14.0)	3.1 (2.5)
Bedrock Park (65.9)	6.4	37	27	260	0.2	79.2 (16.8)	6.8 (4.3)
Matthews Riffle (64.0)	16.7	71	71	270	0.3	95.9 (14.4)	12.7 (6.2)
Steep Riffle (61.0)	26.2	111	111	270	0.5	98.6 (21.3)	15.6 (9.9)
Eye Riffle (60.1)	n/t	14	0	60	0.2	124.6 (23.0)	29.4 (15.5)

n/t = no steelhead tagged at this location

Of the 424 marked steelhead, only 22 (5.2%) were recaptured (Appendix A). As a percentage of steelhead tagged by location, more steelhead were recaptured in Hatchery Ditch (i.e., 17 recaptured out of 215 tagged, 7.9%). Of the 22 recaptures, 86.4% were recaptured in the same location they were initially marked. The largest distance a recaptured steelhead traveled was from Bedrock Park to Steep Riffle, a distance of 4.8 river miles. No marked fish were recovered upstream of their release location. Sixty-two days was the longest duration a marked steelhead was at large. This was a steelhead marked and recaptured in Hatchery Ditch.

The average growth (fork length) at all locations combined for the entire sampling period was 14.5 mm (± 8.85 mm SD). Average growth per day was .52 mm (±.38 mm SD). Average weight gain for the entire sampling period was 3.34 grams (±3.07 mm SD). Average weight gain per day was 0.11 grams (± 0.11 g SD). Condition factor (K) was highest at Steep Riffle (K=1.42) and lowest at Hatchery Ditch and Bedrock Park (K = 1.21) (Figure 3.1-1). The fastest growth observed (for an individual at large more than 7 days) was an individual marked at Matthews

Riffle and recaptured at Steep Riffle 23 days later (1.30 mm/day)(See Appendix A). Size at each location steadily increased throughout sampling (Figures 3.1-2 to 3.1-5.) Average size by location (excluding Eye Riffle because it was sampled only once) over the entire sampling period was greatest at Steep Riffle (mean fork length 98.6 ± 21.3 mm SD) and least at Hatchery Ditch (mean fork length 60.9 ± 10.3 mm SD).

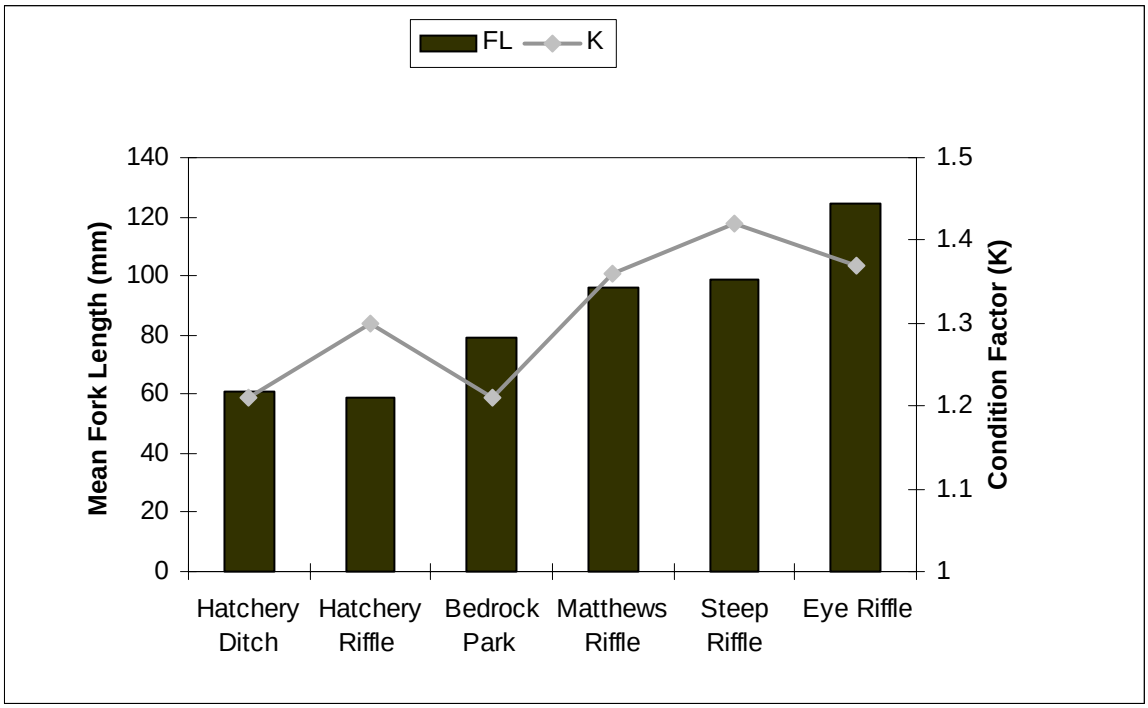


Figure 3.1-1. Mean fork length and condition factors (K) of Steelhead (*Oncorhynchus mykiss*) captured at six low flow channel locations.

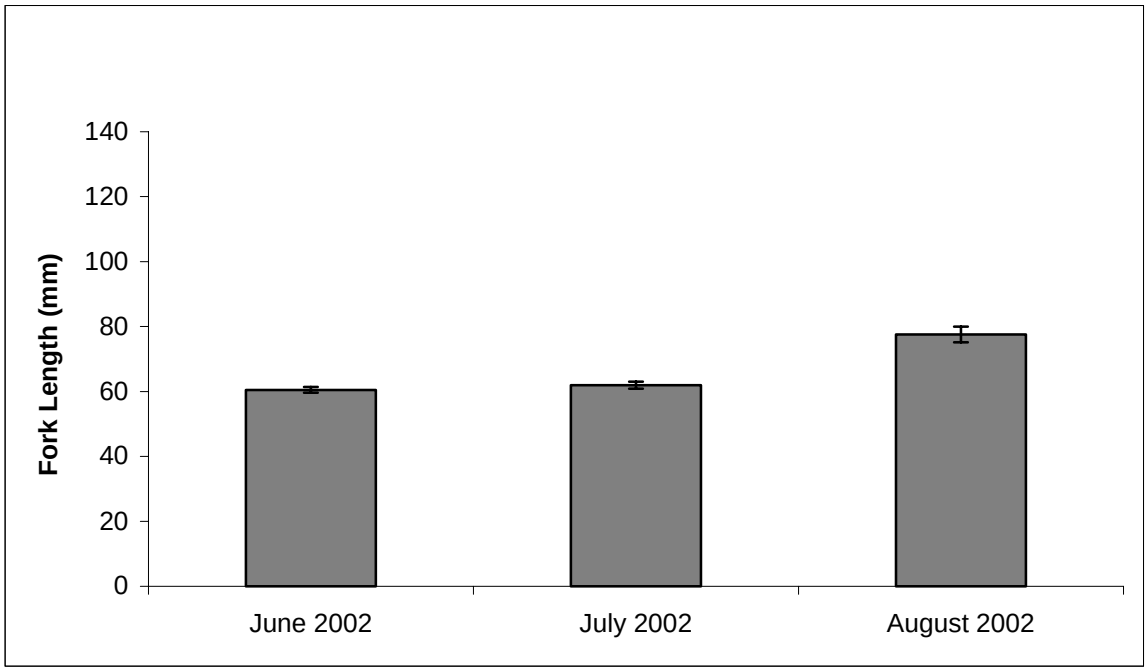


Figure 3.1-2. Mean fork length of juvenile Steelhead (*Oncorhynchus mykiss*) captured monthly in Hatchery Ditch. Standard error bars are shown.

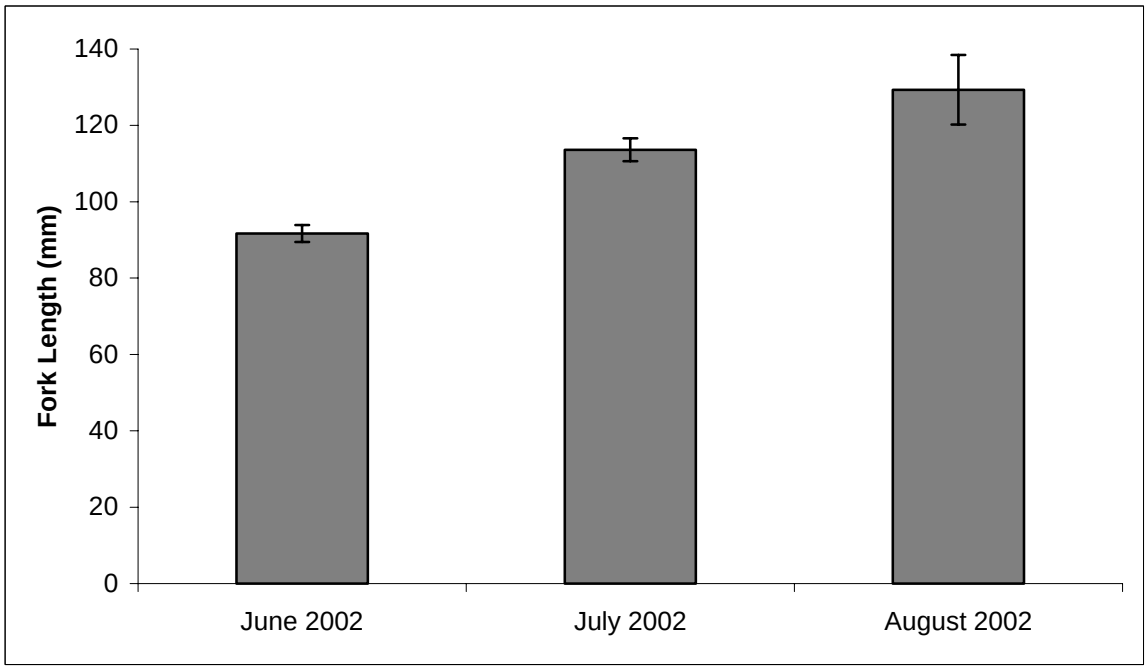


Figure 3.1-3. Mean fork length of juvenile Steelhead (*Oncorhynchus mykiss*) captured monthly in Steep Riffle. Standard error bars are shown.

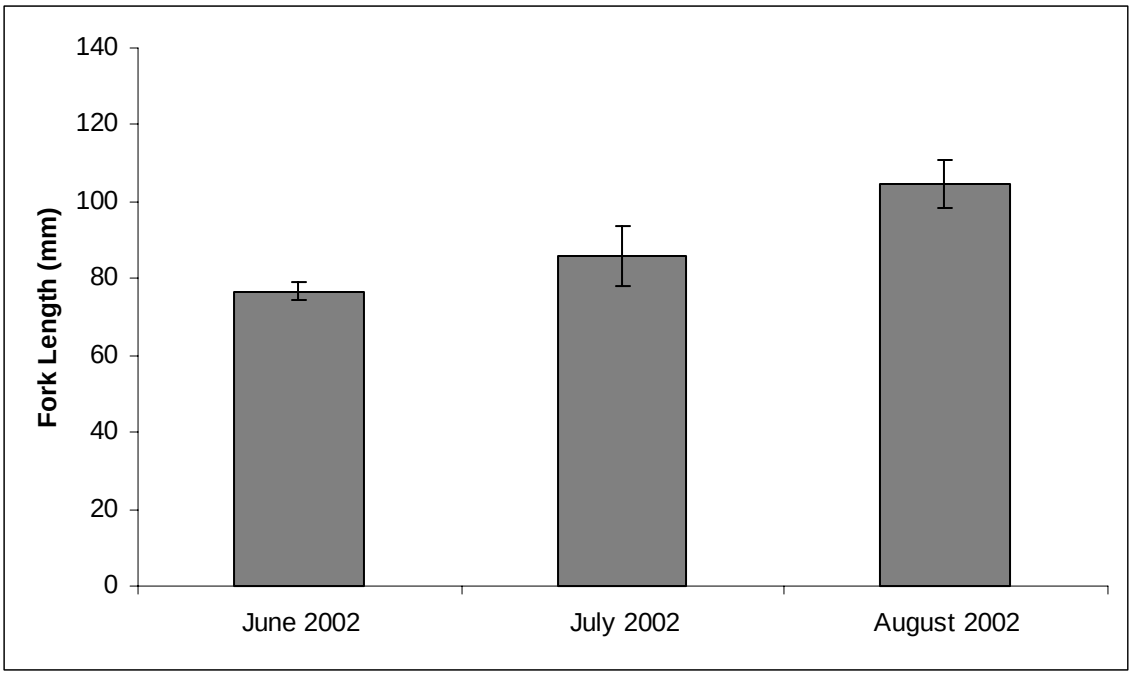


Figure 3.1-4. Mean fork length of juvenile Steelhead (*Oncorhyncus mykiss*) captured monthly in Bedrock Park. Standard error bars are shown.

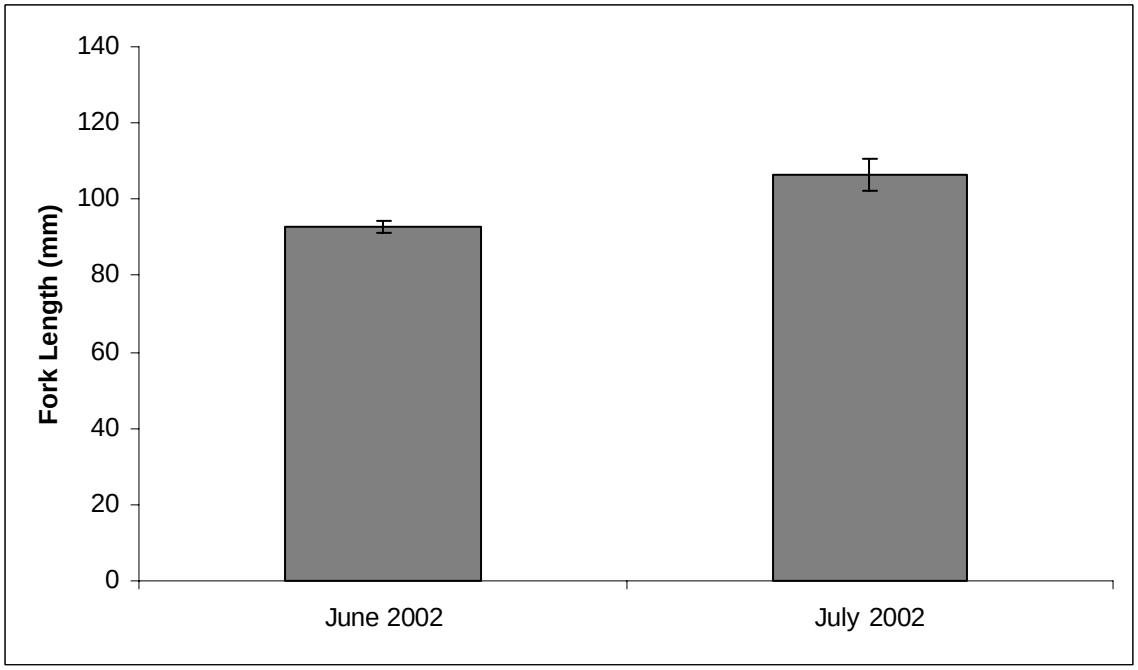


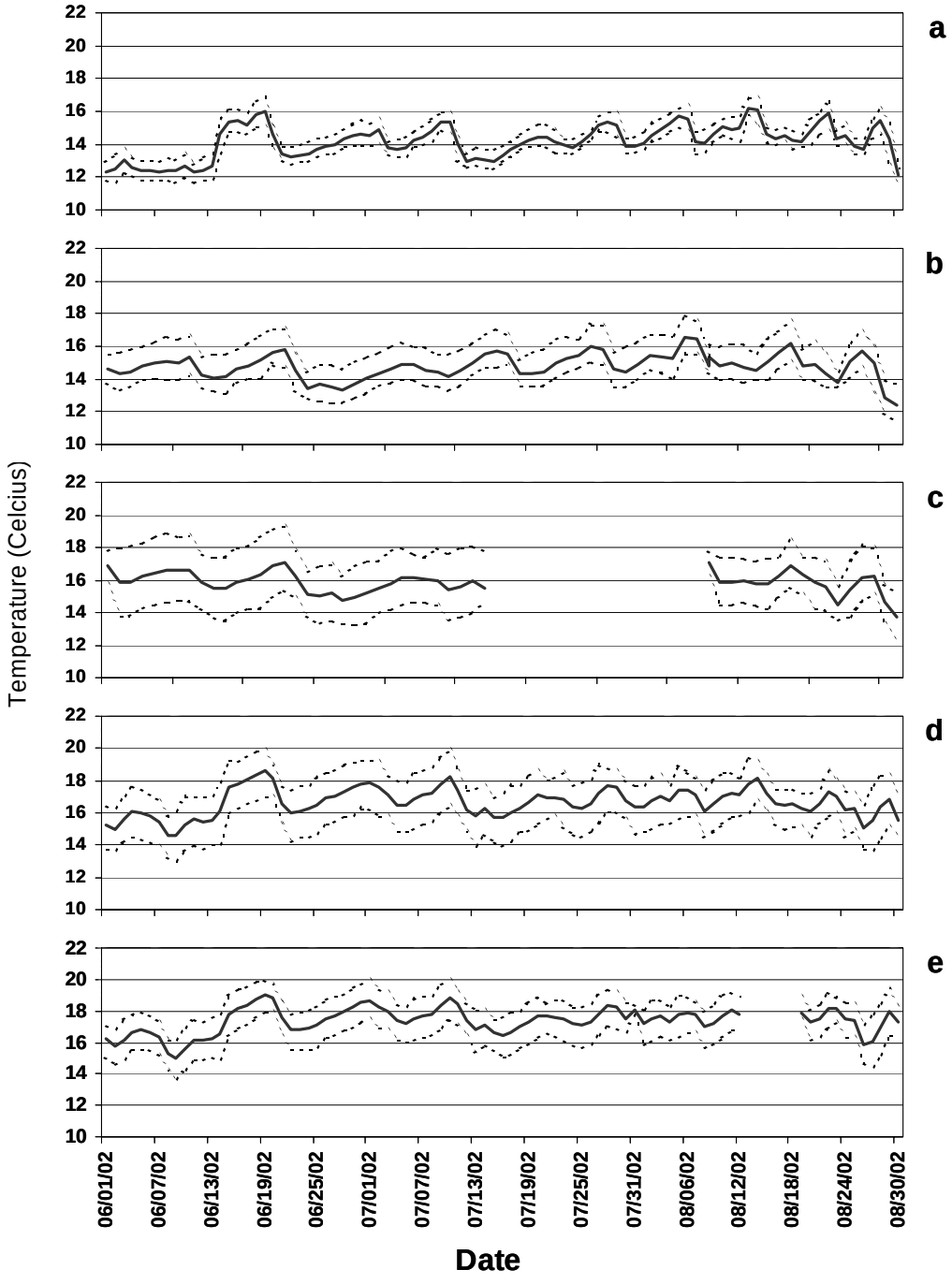
Figure 3.1-5. Mean fork length of juvenile Steelhead (*Oncorhyncus mykiss*) captured monthly in Matthews Riffle. Standard error bars are shown.

3.2 Enclosure Pilot Study

Although the enclosure pilot study did not provide valid growth data, it did allow us to determine future sites for the experiment and help determine the best methods to avoid large-scale vandalism. Future efforts (June-August, 2003) will focus on placing three enclosures at both Hatchery (RM 66.7) and Eye Riffles (RM 60.1). This will provide our best chance to compare the growth of steelhead rearing in two highly different temperature regimes.

3.3 Temperature Profiles

Temperature profiles for five riffle locations are shown in Figure 3.3-1. No temperature profiles were created for Hatchery Ditch and Steep Riffle due to logger malfunction. The Hatchery Ditch profile would closely resemble Auditorium Riffle (due to their upper river location). The Steep Riffle profile would be somewhere between the Robinson Riffle and Eye Riffle profiles. It is clear that the further upstream, the colder the temperatures. Temperatures at each site demonstrate similar patterns of variation, illustrating that the temperatures are changing in response to the same environmental factors.



Source: DWR, unpublished

Figure 3.3-1. Mean daily temperature with daily minimum (--) and maximum (--) for (a) Auditorium Riffle, (b) Bedrock Park, (c) Matthews Riffle, (d) Steep Riffle, and (e) Eye Riffle.

4.0 Summary and Conclusions

Considering the small number of marked and recaptured steelhead, it would be premature to make any final assessments as the growth and site fidelity of wild juvenile Steehead in the LFC of the Feather River. However, some trends are apparent and worth discussing.

Average fork length and condition factor were generally greater further downstream in the LFC. Eye (RM 60.1) and Steep Riffle (RM 61) steelhead maintained the largest average fork length, 124.6 and 98.6 mm, respectively. Steep Riffle steelhead had the highest condition factor (K=1.42). It is difficult to determine whether temperature, food and/or cover is driving the apparent success of steelhead captured at these sites. With such small sample sizes it is premature to make any inferences as to the merit of these results. However, it is likely that a combination of slightly warmer (60-65 F) temperatures, increased food availability and side channel cover could provide a highly suitable rearing environment. What is unknown, however, is how these steelhead fair throughout the entire summer. Nearly all data gathered to this point (at these sites) is from unmarked fish, precluding the discussion of long-term temperature effects on individuals. Future mark and recapture studies will heavily focus on gathering additional data at Steep and Eye Riffles. Furthermore, summer 2003 enclosure studies will gather data on individual fish rearing long-term at Eye riffle, possibly the most downstream (and warmest) summer rearing area in the Feather River.

Growth rate in Hatchery Ditch appears to be slower than downstream areas. Average fork length of all unmarked steelhead captured in Hatchery Ditch only increased 17.1 mm over the entire sampling period. In contrast, average fork length increased 37.7 mm at Steep Riffle (Table 3-1.1). It is unknown whether this reflects the quality of the rearing habitat and water temperature at either location or whether the observed growth is an artifact of sampling. It is clear, however, that steelhead rearing in Steep Riffle are on average much larger than those rearing in Hatchery Ditch (and probably other upstream locations). It is important to remember that the increase in fork length obtained from unmarked fish is not an accurate growth “rate”. However, it does indicate that steelhead rearing in Hatchery Ditch are probably growing slower than fish rearing in other locations. Evidence from the marking experiments supports this theory. Growth of the 15 marked steelhead (from Hatchery Ditch) averaged 13.5 mm ($\pm$ 7.6 mm SD) over an average 30 day sampling interval (.57 mm/day). This is similar to the overall increase in fork lengths obtained from unmarked fish caught in Hatchery Ditch over the same sampling period (.63 mm/day). If most Feather River steelhead exhibit strong site fidelity (as evidenced by Hatchery Ditch), then observed changes in length frequency over time (of unmarked fish) at any one location may adequately reflect the actual growth “rate” at that site. Additionally, since Hatchery Ditch does not connect to the river at its upstream end (thus few immigrants into the area), it is likely that steelhead captured there are the same ones previously captured the month before. Therefore, the growth observed over time would

presumably be a fair estimation of growth. Future mark and recapture studies will focus on tagging and recapturing more steelhead to determine a more accurate growth rate at each location.

The mark and recapture data collected in 2002 provides an excellent starting point to refine and expand the 2003 study. Mark and recapture studies will be expanded in 2003, increasing the available information on wild steelhead growth in the Feather River.

Additionally, enclosure experiments will be expanded by placing three enclosures at both Hatchery and Eye Riffles. Enclosures will also be retrofitted to prevent large-scale vandalism and subsequent destruction of the experimental units. These measures will allow a more detailed analysis of the effects of long term rearing of Feather River steelhead in different temperature settings.

5.0 References

DWR and USBR (U.S. Bureau of Reclamation). 2000. Biological Assessment, Effects of the Central Valley Project and State Water Project Operations on Steelhead and Spring-Run Salmon, Sacramento. November 2000.

Myrick, 1998. Growth and Thermal Biology of Feather River Steelhead Under Constant and Cyclical Temperatures. (Draft Report).

Appendix A. Summary table of all Steelhead marked and recaptured during the 2002 sampling period. BP=Bedrock Park, HD=Hatchery Ditch, SR=Steep Riffle.

Tagging Location	Tag Date	Recap Date	Recap Site	Original FL (mm)	Recap FL	Original Wt (g)	Recap Weight	Length Diff	Weight Diff	Days to recap	Length growth/ day (mm)	Weight growth/ day (g)
BP	7/30	8/22	SR	73	103	4.18	16.68	30	12.5	36	0.83	0.35
BP	6/20	8/21	BP	83	113	7.02	17.36	30	10.34	36	0.83	0.29
BP	6/20	7/25	BP	58	82	2.61	6.81	24	4.2	36	0.67	0.12
HD	6/18	6/24	MR	54	64	2.1	2.75	10	0.65	35	0.29	0.02
HD	6/18	7/24	HD	44	68	1.5	4.34	24	2.84	35	0.69	0.08
HD	6/18	6/20	BP	58	58	1.8	1.78	0	-0.02	2	0.00	-0.01
HD	6/18	7/24	HD	47	57	1.3	2.06	10	0.76	6	1.67	0.13
HD	7/24	8/21	HD	68	83	3.93	7.68	15	3.75	28	0.54	0.13
HD	7/24	8/21	HD	59	67	2.32	3.5	8	1.18	28	0.29	0.04
HD	7/24	8/21	HD	55	65	2.05	3.59	10	1.54	28	0.36	0.06
HD	7/24	8/21	HD	52	57	1.55	2.74	5	1.19	28	0.18	0.04
HD	7/24	8/21	HD	55	59	1.7	2.76	4	1.06	28	0.14	0.04
HD	7/24	8/21	HD	69	75	4.12	5.83	6	1.71	28	0.21	0.06
HD	7/24	8/21	HD	53	68	1.82	3.89	15	2.07	28	0.54	0.07
HD	7/24	8/21	HD	53	68	2.15	3.88	15	1.73	28	0.54	0.06
HD	7/24	8/21	HD	63	83	3.06	6.86	20	3.8	28	0.71	0.14
HD	7/24	8/21	HD	69	76	4.51	5.61	7	1.1	28	0.25	0.04
HD	7/24	8/21	HD	70	83	3.79	7.78	13	3.99	28	0.46	0.14
HD	7/24	8/21	HD	63	82	2.83	7.16	19	4.33	28	0.68	0.15
HD	6/18	7/24	HD	55	86	2.4	7.46	31	5.06	62	0.50	0.08
SR	6/25	7/30	SR	94	105	11.9	17.03	11	5.13	23	0.48	0.22
SR	7/30	8/22	SR	109	121	18.08	22.56	12	4.48	23	0.52	0.19